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Application Number : 200302854-5

Applicant(s) /
Proprietor(s) of Patent : SENSFAB PTE LTD

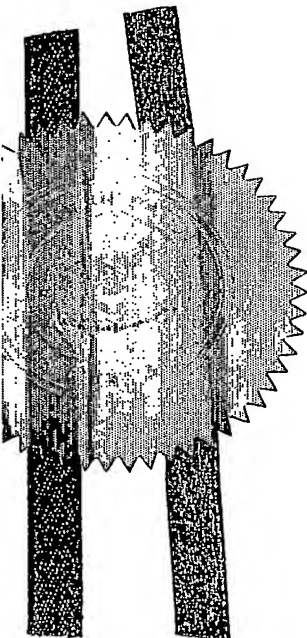
Title of Invention : FABRICATION OF SILICON
MICROPHONES

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REQUEST FOR THE GRANT OF A PATENT UNDER
SECTION 25

101101

* denotes mandatory fields

1. YOUR REFERENCE*

MI/LWC/muha/PAT/8113417/SG

2. TITLE OF
INVENTION*

FABRICATION OF SILICON MICROPHONES

3. DETAILS OF APPLICANT(S)* (see note 3)

Number of applicant(s)

01

(A) Name

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SG

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For corporate applicant

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For individual applicant

State of incorporation

State of residency

Country of incorporation

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Country of residency

☐

For others (please specify in the box provided below)

(B) Name

Address

State

Country



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For corporate applicant

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State of incorporation

State of residency

Country of incorporation

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(C) Name

Address

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Country

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For corporate applicant

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For individual applicant

State of incorporation

State of residency

Country of incorporation

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For others (please specify in the box provided below)

☐

Further applicants are to be indicated on continuation sheet 1

4. DECLARATION OF PRIORITY (see note 5)

A. Country/country designated

DD MM YYYY

File number

Filing Date

B. Country/country designated

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Further details are to be indicated on continuation sheet 6

5. INVENTOR(S)* (see note 6)

A. The applicant(s) is/are the sole/joint inventor(s)

Yes

☐

No

☒

B. A statement on Patents Form 8 is/will be furnished

Yes

☐

No

☒

6. CLAIMING AN EARLIER FILING DATE UNDER (see note 7)

☐

section 20(3)

☐

section 26(6)

☐

section 47(4)

Patent application number

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Filing Date

Please mark with a cross in the relevant checkbox provided below
(Note: Only one checkbox may be crossed)

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Proceedings under rule 27(1)(a)

DD MM YYYY

Date on which the earlier application was amended

☐

Proceedings under rule 27(1)(b)

7. SECTION 14(4)(C) REQUIREMENTS (see note 8)

Invention has been displayed at an international exhibition

Yes

☐

No

☒

8. SECTION 114 REQUIREMENTS (see note 9)

The invention relates to and/or used a micro-organism deposited for the purposes of disclosure in accordance with section 114 with a depository authority under the Budapest Treaty.

Yes

☐

No

☒

9. CHECKLIST*

(A) The application consists of the following number of sheets

i.	Request	<input type="text" value="5"/>	Sheets
ii.	Description	<input type="text" value="12"/>	Sheets
iii.	Claim(s)	<input type="text" value="4"/>	Sheets
iv.	Drawing(s)	<input type="text" value="4"/>	Sheets
v.	Abstract (Note: The figure of the drawing, if any, should accompany the abstract)	<input type="text" value="1"/>	Sheets
Total number of sheets		<input type="text" value="26"/>	Sheets

(B) The application as filed is accompanied by.

☐

Priority document(s)

☐

Translation of priority document(s)

☐

Statement of inventorship
& right to grant

☐

International exhibition certificate

10. DETAILS OF AGENT (see notes 10, 11 and 12)

Name

Firm

DREW & NAPIER LLC

11. ADDRESS FOR SERVICE IN SINGAPORE* (see note 10)

Block/Hse No.

Level No

Unit No /PO Box

152

Street Name

ROBINSON ROAD

Building Name

Postal Code

900302

12. NAME, SIGNATURE AND DECLARATION (WHERE APPROPRIATE) OF APPLICANT OR AGENT* (see note 12)

(Note. Please cross the box below where appropriate.)

☒

I, the undersigned, do hereby declare that I have been duly authorised to act as representative, for the purposes of this application, on behalf of the applicant(s) named in paragraph 3 herein.

Name and Signature
(DREW & NAPIER LLC)

DD MM YYYY

26/05/2003

NOTES:

1. This form when completed, should be brought or sent to the Registry of Patents together with the rest of the application. Please note that the filing fee should be furnished within the period prescribed.
2. The relevant checkboxes as indicated in bold should be marked with a cross where applicable
3. Enter the name and address of each applicant in the spaces provided in paragraph 3
Where the applicant is an individual
 - Names of individuals should be indicated in full and the surname or family name should be underlined.
 - The address of each individual should also be furnished in the space provided
 - The checkbox for "For individual applicant" should be marked with a cross.Where the applicant is a body corporate
 - Bodies corporate should be designated by their corporate name and country of incorporation and, where appropriate, the state of incorporation within that country should be entered where provided
 - The address of the body corporate should also be furnished in the space provided
 - The checkbox for "For corporate applicant" should be marked with a cross.Where the applicant is a partnership
 - The details of all partners must be provided. The name of each partner should be indicated in full and the surname or family name should be underlined
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4. In the field for "Country", please refer to the standard list of country codes made available by the Registry of Patents and enter the country code corresponding to the country in question.
5. The declaration of priority in paragraph 4 should state the date of the previous filing, the country in which it was made, and indicate the file number, if available. Where the application relied upon in an International Application or a regional patent application e.g. European patent application, one of the countries designated in that application [being one falling under section 17 of the Patents Act] should be identified and the country should be entered in the space provided
6. Where the applicant or applicants is/are the sole inventor or the joint inventors, paragraph 5 should be completed by marking with a cross the 'YES' checkbox in the declaration (A) and the 'NO' checkbox in the alternative statement (B). Where this is not the case, the 'NO' checkbox in declaration (A) should be marked with a cross and a statement will be required to be filed on Patents Form 8.
7. When an application is made by virtue of section 20(3), 26(6) or 47(4), the appropriate section should be identified in paragraph 6 and the number of the earlier application or any patent granted thereon identified. Applicants proceeding under section 26(6) should identify which provision in rule 27 they are proceeding under. If the applicants are proceeding under rule 27(1)(a), they should also indicate the date on which the earlier application was amended.
8. Where the applicant wishes an earlier disclosure of the invention by him at an International Exhibition to be disregarded in accordance with section 14(4)(c), then the 'YES' checkbox at paragraph 7 should be marked with a cross. Otherwise, the 'NO' checkbox should be marked with a cross.
9. Where in disclosing the invention the application refers to one or more micro-organisms deposited with a depository authority under the Budapest Treaty, then the 'YES' checkbox at paragraph 8 should be marked with a cross. Otherwise, the 'NO' checkbox should be marked with a cross. Attention is also drawn to the Fourth Schedule of the Patents Rules
10. Where an agent is appointed, the fields for "DETAILS OF AGENT" and "ADDRESS FOR SERVICE IN SINGAPORE" should be completed and they should be the same as those found in the corresponding Patents Form 41. In the event where no agent is appointed, the field for "ADDRESS FOR SERVICE IN SINGAPORE" should be completed, leaving the field for "DETAILS OF AGENT" blank.
11. In the event where an individual is appointed as an agent, the sub-field "Name" under "DETAILS OF AGENT" must be completed by entering the full name of the individual. The sub-field "Firm" may be left blank. In the event where a partnership/body corporate is appointed as an agent, the sub-field "Firm" under "DETAILS OF AGENT" must be completed by entering the name of the partnership/body corporate. The sub-field "Name" may be left blank.
12. Attention is drawn to sections 104 and 105 of the Patents Act, rules 90 and 105 of the Patents Rules, and the Patents (Patent Agents) Rules 2001.
13. Applicants resident in Singapore are reminded that if the Registry of Patents considers that an application contains information the publication of which might be prejudicial to the defence of Singapore or the safety of the public, it may prohibit or restrict its publication or communication. Any person resident in Singapore and wishing to apply for patent protection in other countries must first obtain permission from the Singapore Registry of Patents unless they have already applied for a patent for the same invention in Singapore. In the latter case, no application should be made overseas until at least 2 months after the application has been filed in Singapore, and unless no directions had been issued under section 33 by the Registrar or such directions have been revoked. Attention is drawn to sections 33 and 34 of the Patents Act.
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G00002

FABRICATION OF SILICON MICROPHONES



159159

FIELD OF INVENTION

- 5 The invention relates to silicon microphones and in particular to the fabrication of silicon microphones.

BACKGROUND

- 10 A capacitive microphone typically includes a diaphragm including an electrode attached to a flexible member and a backplate parallel to the flexible member attached to another electrode. The backplate is relatively rigid and typically includes a plurality of holes to allow air to move between the backplate and the flexible member. The backplate and flexible member form the parallel plates of a capacitor. Acoustic pressure on the
15 diaphragm causes it to deflect which changes the capacitance of the capacitor. The change in capacitance is processed by electronic circuitry to provide an electrical signal that corresponds to the change.

- Microelectronic mechanical devices (MEMS), including miniature microphones, are
20 fabricated with techniques commonly used for making integrated circuits. Potential uses for MEMS microphones include microphones for hearing aids and mobile telephones, and pressure sensors for vehicles.

- Many available MEMS microphones involve a complex fabrication process that
25 includes numerous masking and etching steps. As the complexity of the fabrication process increases there is a greater risk of the devices failing the testing process and being unusable.

SUMMARY OF INVENTION

30

It is the object of the present invention to provide a fabrication process for silicon microphones that has a low number of process steps or to at least provide the public with a useful choice.

5 In broad terms the invention comprises a method of manufacturing a silicon microphone including the steps of:

- providing a first wafer including a layer of heavily doped silicon, a layer of silicon and an intermediate layer of oxide between the two silicon layers and having a first major surface on one surface of the layer of heavily doped silicon and a second major surface on the layer of silicon,
- 10 providing a second wafer of silicon having a first major surface and a second major surface,
- forming a layer of oxide on at least the first major surface of the first wafer,
- forming a layer of oxide on at least the first major surface of the second wafer,
- 15 etching a cavity through the oxide layer on the first major surface of the first wafer and into the layer of heavily doped silicon,
- bonding the first major surface of the first wafer to the first major surface of the second wafer,
- thinning the first wafer at its second major surface,
- 20 forming a metal layer on the second major surface of the second wafer,
- patterning and etching acoustic holes in the metal and in the second major surface of the second wafer,
- etching the intermediate layer of oxide from the first wafer, and
- forming at least one electrode on the heavily doped silicon of the first wafer and
- 25 at least one electrode on the second wafer.

Preferably the step of forming an oxide layer on at least one major surface of both wafers includes forming an oxide layer on both major surfaces of both wafers.

30 Preferably the oxide layers formed on the major faces of the wafers are grown on the major surfaces of the wafers. Alternatively any other suitable method may be used to form the oxide layers.

If an oxide layer is formed on the second major surface of the second wafer, preferably this layer is removed before the first wafer is thinned.

- 5 If an oxide layer is formed on the second major surface of the first wafer, preferably this layer is removed before the first wafer is thinned.

The step of forming a layer of metal on the other major surface of the second wafer may be by sputtering metal onto the second major surface of the second wafer.

10

In one embodiment the invention further comprises etching a portion of the second major wafer from its second major surface to close to its first major surface, the portion being about the perimeter of the wafer. Preferably this etching is performed when the acoustic holes are etched.

15

Preferably when the first wafer is thinned at its second major surface, the first wafer is thinned to the intermediate oxide layer.

20

In one embodiment the step of forming electrodes on the heavily doped silicon layer of the first wafer and on the second wafer is performed by forming a metal electrode layer over the entire exposed surface of the heavily doped silicon layer of the first wafer and the exposed surface of the first major surface of the second wafer. This layer of metal is then etched to form the electrodes.

25

In an alternative embodiment the step of forming electrodes on the heavily doped silicon layer of the first wafer and on the second wafer may be performed by sputtering metal and using a shadow mask to pattern the electrodes.

30

In one embodiment the layer of metal formed on the second major surface of the second wafer is an alloy or mixture of chromium and gold. Alternatively any other suitable conductive metal may be used for the electrode.

When the acoustic holes are patterned and etched into the metal layer formed on the second major surface of the second wafer, anchors are generally patterned and formed at the edges of the wafer in the metal layer formed on the second major surface of the second wafer. One of these anchors may be used as an electrode. The other anchors
5 may include both a portion of the second wafer and a cover portion of metal. The cover metal portions are ideally separated from the metal surrounding the acoustic holes. The separation step may be performed by patterning and etching the separation when the acoustic holes are patterned and etched in the metal.

10 In broad terms in another aspect the invention comprises a silicon microphone formed using the method of the invention.

BRIEF DESCRIPTION OF DRAWINGS

15 The method of fabricating a silicon microphone will be further described by way of example only and without intending to be limiting with reference to the following drawings, wherein:

Figure 1A is a side view of the first wafer before fabrication;

20

Figure 1B is a side view of the second wafer before fabrication;

Figure 2A is a side view of the first wafer after the deposition or growth of oxide;

25 Figure 2B is a side view of the second wafer after the deposition or growth of oxide;

Figure 3 is a side view of the first wafer after a cavity has been patterned and etched;

Figure 4 is a side view of the two wafers bonded together;

30

Figure 5 is a side view of the two wafers after the oxide layers have been stripped;

Figure 6 is a side view of the two wafers after thinning the first wafer;

Figure 7 is a side view of the two wafers after forming metal on the second wafer and forming acoustic holes in the second wafer;

5

Figure 7A is a second side view of the two wafers after forming metal on the second wafer and forming acoustic holes in the second wafer taken about line A-A on Figure 11;

10 Figure 8 is a side view of the two wafers after etching oxide from the bond between the two wafers;

Figure 8A is a second side view of the two wafers after etching oxide from the bond between the two wafers taken about line A-A of Figure 11;

15

Figure 9 is a side view of the two wafers after forming metal over the heavily doped layer of the first wafer;

20 Figure 9A is a second side view of the two wafers after forming metal over the heavily doped layer of the first wafer taken about line A-A of Figure 11;

Figure 10 is a side view of the two wafers after electrodes have been formed;

25 Figure 10 A is a second side view of the two wafers after electrodes have been formed taken about line A-A of Figure 11; and

Figure 11 is a top view of the completed silicon microphone.

DETAILED DESCRIPTION

30

Figure 1A is a side view of the first wafer used for fabricating a silicon microphone. This wafer is formed from a first layer 1 of highly doped silicon, a middle layer 2 of

oxide and the third layer 3 of silicon substrate. In one embodiment the first layer is p^{++} doped silicon and the third layer is an n-type substrate. In an alternative embodiment the first layer may be n^{++} doped silicon and the third layer may be a p-type substrate. Typically the first layer 1 is of the order of 4 microns thick and the second layer is of the order of 2 microns thick. The thickness of these layers used in the silicon microphone will depend on the required characteristics of the microphone. The substrate layer is thicker than the other two layers and for example may be of the order of about 400 to 600 microns thick.

10 It should be noted that the side views shown are not drawn to scale and are given for illustrative purposes only.

Figure 1B is a side view of the second wafer used for fabricating a silicon microphone. This wafer comprises a silicon wafer 4. The wafer is heavily doped silicon and may be either p-type or n-type silicon. In a preferred embodiment the wafer is $\langle 100 \rangle$ silicon. In other embodiments different silicon surfaces or structures may be used.

Although Figures 1A and 1B are side views of the two wafers, the wafers are three dimensional with two major surfaces. The two major surfaces of the first wafer are the top and bottom surfaces (not shown in Figure 1A). The first major surface, the top surface, comprises highly doped silicon. The second major surface, the bottom surface, comprises the silicon substrate.

In Figure 1B the major surfaces are at the top and bottom of the wafer and both comprise the heavily doped silicon wafer.

In fabricating the silicon microphone the two wafers are initially processed separately before being bonded together and further processed.

30 Figures 2A and 2B show the first and second wafers after oxide 5 has been formed on the major surfaces of the wafers. Oxide is typically formed on both surfaces of both wafers through thermal growth or a deposition process. Forming oxide on both major

surfaces of each wafer reduces the risks of distorting the wafer that would occur if oxide was formed on only one side of each wafer. In an alternative embodiment oxide is formed on only one major surface of each wafer. As can be seen in Figure 2A and 2B the thickness of the oxide layers 5 is less than the thickness of the silicon wafer.

5

It is to be understood that any other suitable dielectric or insulative material, for example silicon nitride, may be used in place of the oxide layer.

10

Figure 3 shows one embodiment in which a cavity 6 is patterned and etched into the first major surface of the first wafer. In this step a portion of the heavily doped silicon layer is etched away to produce a thin section of the heavily doped portion 1. A wet or dry silicon etch may be used. The thickness of the thin section determines properties of the silicon microphone as this section will eventually form the diaphragm of the microphone. In one embodiment a reactive ion etch (RIE) is used to form the cavity.

15

This etch is a time etch so the final thickness of the thin section of the heavily doped portion depends on the etching time.

The desired shape of the cavity is determined from the required properties of the silicon microphone.

20

As shown in Figure 4 the two wafers are bonded together. The major surfaces bonded together are the first major surface 1 of the first wafer and one of the major surfaces of the second wafer 4. In a preferred embodiment the two wafers are bonded together using fusion bonding. As shown in Figure 4 it is the oxide layer 5 of second wafer 4 and the patterned oxide layer 5 of the first wafer that are bonded together.

25

Figure 5 shows the two wafers after the oxide layers are stripped from the exposed major surfaces of these wafers. Oxide stripping is well known and any suitable technique may be used to strip the oxide from the exposed surfaces.

30

Figure 6 shows the two wafers after the silicon substrate has been removed from the first wafer. In the preferred embodiment this thinning is performed in a single

operation. Any suitable technique may be used to remove the layer of substrate from the first wafer.

5 After thinning of the first wafer acoustic holes are patterned and etched into the second wafer as shown in Figure 7. To pattern and etch the acoustic holes the first step is to form a layer of metal 7 on the outer major surface of the second wafer 4. In one embodiment metal is sputtered onto the major surface of the second wafer. The metal is then covered with a layer of resist and the resist is then patterned. Etching is performed to etch the acoustic holes through the metal 7 and silicon 4. The etching may also etch 10 the oxide layer 5 at the bottom of the acoustic holes to provide access between the acoustic holes and the cavity formed in the heavily doped silicon layer 1 of the first wafer.

15 The metal may be a combination of chromium and gold or any other suitable metal or metal combination, for example titanium or aluminium. In one embodiment the metal 7 is patterned and etched to include corner anchor pads by which the microphone may be attached to an underlying carrier.

Figure 11 shows the perforated and metallised silicon layer and the corner anchor pads. 20 If a connection to the silicon layer 4 of the second wafer is made from the other side, all pads can be disconnected from the metal layer 7, as shown in Figure 11. If, for example, one of the anchor pads is used as an electrode to connect to the silicon layer 4 of the second wafer, the other anchor pads may be separated from the remainder of the metal layer. Separation of the anchor pads from the bulk of the metal reduces noise 25 contribution from the anchor pads. The separation is patterned and etched with the rest of the metal.

30 The acoustic holes or apertures in the silicon wafer may be circular and set within a rectangle of the silicon wafer with its centre at the centre of the silicon wafer stack but with length and breadth less than that of the wafer stack. The shape and arrangement of the apertures is chosen to provide suitable acoustic performance from the microphone.

Figure 7A shows a representative diagrammatic side view of the silicon microphone taken through lines A-A of the plan view of Figure 11. This shows the different layers of the silicon microphone in different regions of the microphone. As can be seen in Figure 7A metal layer 7 does not cover the whole of the second major surface of silicon wafer 4.

As can also be seen in Figures 7 and 7A the cavity in the first wafer is larger than the area defined by the acoustic holes of the second wafer. By providing a bigger cavity 6 for the diaphragm 1 of the first wafer the required accuracy of the position of the acoustic holes is lessened.

As also shown in Figure 7 during the etching of the acoustic holes a small area or gap around the perimeter of the silicon microphone may also be etched. In the preferred embodiment this etching is performed by a reactive ion etch-lag (RIE-lag). The RIE-lag is a phenomenon by which, in this case, the smaller dimensioned perimeter gap in the resist mask etches to a lesser depth than the larger dimensioned acoustic holes. Because of the RIE-lag, the gap about the perimeter of the silicon microphone does not completely etch through the silicon layer 4. This gap is shown as a step in the side views of Figures 7 to 10A. The incompletely etched perimeter provides lines of weakness where the bonded wafer will break when stressed, i.e. when subjected to pressure by a roller. Forming this incomplete etch allows dicing of the wafer, into individual microphone chips, without the use of abrasives or wet processes thereby reducing possible damage to the fragile diaphragm. The partial etch should be sufficiently deep to allow easy breakage of the wafer at dicing but shallow enough to allow easy handling of the wafer without breakage before dicing.

Figures 8 and 8A show the result of further patterning and etch steps on the bonded wafers. In these steps the oxide layer 2 is patterned to define an isolated area of the heavily doped silicon 1 which is then etched. The oxide layer 2 is then etched away from the heavily doped silicon layer 1. The oxide layers 5 around the isolated area of the diaphragm are etched away to expose portions of the generally inner major face of the second wafer 4. The oxide layer 5 inside the acoustic holes is etched away. In the

case of using RIE, the opposite faces of the combined silicon wafer are etched in separate steps. After these etch steps, the remaining portion of the highly doped silicon 1, as defined by the isolated area, is less than the length of the large portion of the silicon 4 of the second wafer (excluding the partially etched silicon at the perimeter of the silicon microphone).

Figure 9 shows one embodiment with a layer of metal formed over the heavily doped silicon layer of the first wafer and the exposed silicon of the second wafer. As shown in Figure 9 this metal layer is sputtered globally. The metal is then etched to form at least two electrodes 10, 11 as shown in Figure 10. At least one electrode 11 is formed on the layer of heavily doped silicon and at least one electrode 10 is formed on the exposed first, inner, major face of the silicon 4 of the second wafer.

In another embodiment the electrodes 10, 11 are formed by using a shadow mask to deposit metal directly in the required pattern.

As can be seen in Figure 10 electrode 11 is in contact with the heavily doped layer of the first wafer 1 and electrode 10 is in contact with the silicon layer 4 of the second wafer. This allows the microphone to be connected to another device by connection bonds made from only one side of the microphone. Alternatively, as there is a layer of metal 7 on the other side of the microphone this can be used as the electrode of the silicon 4 of the second wafer and can be connected to an underlying carrier by solder, conductive paste, or any other suitable method. By providing two electrodes for the second wafer, on opposite faces of the wafer, packaging flexibility is achieved.

Providing two electrodes on one side of the silicon microphone can also assist in probing of the silicon microphone, for example before the microphone is attached to a carrier or other system. Probing of the silicon microphone can be performed by probing needles on one side of the microphone only instead of needles on two sides of the microphone.

Embodiments of the invention will be further illustrated by the following examples.

Example

Two wafers are provided; the first wafer comprises a 4 micron layer of p^{++} doped silicon, a 2 micron oxide layer, and an n-type substrate; the second wafer comprises n-type silicon.

A layer of oxide of about 1 micron is grown on each major surface of the two wafers by thermal growth. The oxide layer is then etched from a portion of the first wafer and an underlying portion of the p^{++} doped silicon layer is also etched to provide a cavity in the p^{++} doped silicon of about 2 microns. The etching is a dry reactive ion etch.

The cavity side of the first wafer is then fusion bonded to an oxide covered surface of the second wafer and the outer oxide layers of each wafer are stripped. The silicon substrate of the first wafer is also stripped using a suitable stripping technique for example lapping, grinding or etching.

Chromium/gold is then sputtered onto the exposed major surface of the second wafer and patterned to form the openings for acoustic holes and for areas of thinned and weakened silicon along the perimeters of the wafer. The mass of silicon in the second wafer is used to provide rigidity to the silicon microphone.

A reactive ion etch is performed to etch acoustic holes in the silicon. Reactive ion etch lag causes the etch at the perimeter of the silicon microphone wafer to etch at a slower rate and therefore a lesser depth, as the resist provides a smaller surface area for etching than that of the acoustic holes. The metal is then further etched to separate three of the corner pads from the bulk of the metal and to further define the metal area.

Following this, oxide is etched from the acoustic holes and the outer oxide layer of the first wafer is also etched away. After this step the p^{++} layer of silicon and the layers of oxide between the two wafers are etched around the perimeter of the wafer to expose a portion of the front, now inner, surface of the silicon of the second wafer.

Metal is then sputtered over the p^{++} layer of silicon and the exposed portions of silicon from the second wafer. The metal is patterned etched to form two electrodes.

The foregoing describes the invention including preferred forms thereof. Alterations
5 and modifications as will be obvious to those skilled in the art are intended to be incorporated in the scope hereof as defined by the accompanying claims.

CLAIMS

1. A method of manufacturing a silicon microphone including the steps of:
 - providing a first wafer including a layer of heavily doped silicon, a layer of
5 silicon and an intermediate layer of oxide between the two silicon layers and having a first major surface on one surface of the layer of heavily doped silicon and a second major surface on the layer of silicon,
 - providing a second wafer of silicon having a first major surface and a second
major surface,
 - 10 forming a layer of oxide on at least the first major surface of the first wafer,
forming a layer of oxide on at least the first major surface of the second wafer,
etching a cavity through the oxide layer on the first major surface of the first
wafer and into the layer of heavily doped silicon,
 - bonding the first major surface of the first wafer to the first major surface of the
15 second wafer,
 - thinning the first wafer at its second major surface,
 - forming a metal layer on the second major surface of the second wafer,
 - patterning and etching acoustic holes in the metal and in the second major
surface of the second wafer,
 - 20 etching the intermediate layer of oxide from the first wafer, and
forming at least one electrode on the heavily doped silicon of the first wafer and
at least one electrode on the second wafer.
2. A method of manufacturing a silicon microphone as claimed in claim 1 wherein
25 the step of forming an oxide layer on at least one major surface of both wafers includes
forming an oxide layer on both major surfaces of both wafers.
3. A method of manufacturing a silicon microphone as claimed in claim 1 or
claim 2 wherein the oxide layers formed on the major faces of the wafers are grown on
30 the major surfaces of the wafers.

4. A method of manufacturing a silicon microphone as claimed in claim 1 or claim 2 wherein any other suitable method is used to form the oxide layers.
5. A method of manufacturing a silicon microphone as claimed in claim 2 wherein the oxide layer formed on the second major surface of the second wafer is removed before the first wafer is thinned.
6. A method of manufacturing a silicon microphone as claimed in claim 2 wherein the oxide layer formed on the second major surface of the first wafer is removed before the first wafer is thinned.
7. A method of manufacturing a silicon microphone as claimed in any one of claims 1 to 6 wherein the step of forming a layer of metal on the second major surface of the second wafer is performed by sputtering metal onto the second major surface of the second wafer.
8. A method of manufacturing a silicon microphone as claimed in any one of claims 1 to 7 further including the step of etching a portion of the second wafer from its second major surface to close to its first major surface, the portion being about the perimeter of the wafer.
9. A method of manufacturing a silicon microphone as claimed in claim 8 wherein the etching of the perimeter portion of the second wafer is performed when the acoustic holes are etched.
10. A method of manufacturing a silicon microphone as claimed in any one of claims 1 to 9 wherein when the first wafer is thinned at its second major surface, the first wafer is thinned to the intermediate oxide layer.
11. A method of manufacturing a silicon microphone as claimed in any one of claims 1 to 10 wherein the step of forming electrodes on the heavily doped silicon layer of the first wafer and on the second wafer is performed by forming a metal electrode

layer over the entire exposed surface of the heavily doped silicon layer of the first wafer and the exposed surface of the first major surface of the second wafer.

12. A method of manufacturing a silicon microphone as claimed in claim 11
5 wherein the metal electrode layer is etched to form the electrodes.

13. A method of manufacturing a silicon microphone as claimed in any one of
claims 1 to 10 wherein the step of forming electrodes on the heavily doped silicon layer
of the first wafer and on the second wafer is performed by sputtering metal and using a
10 shadow mask to pattern the electrodes.

14. A method of manufacturing a silicon microphone as claimed in any one of
claims 1 to 13 wherein the layer of metal formed on the second major surface of the
second wafer is an alloy or mixture of chromium and gold.
15

15. A method of manufacturing a silicon microphone as claimed in any one of
claims 1 to 14 wherein any suitable conductive metal is used for the electrode.

16. A method of manufacturing a silicon microphone as claimed in any one of
20 claims 1 to 15 wherein when the acoustic holes are patterned and etched into the metal
layer formed on the second major surface of the second wafer, anchors are patterned
and formed at the edges of the wafer in the metal layer formed on the second major
surface of the second wafer.

25 17. A method of manufacturing a silicon microphone as claimed in claim 16
wherein one of the anchors may be used as an electrode.

18. A method of manufacturing a silicon microphone as claimed in claim 17
wherein the other anchors include both a portion of the second wafer and a cover
30 portion of metal.

19. A method of manufacturing a silicon microphone as claimed in claim 18 wherein the cover metal portions are separated from metal surrounding the acoustic holes.
- 5 20. A method of manufacturing a silicon microphone as claimed in claim 19 wherein the separation step is performed by patterning and etching the separation when the acoustic holes are patterned and etched in the metal.
21. A silicon microphone formed using the method of any one of claims 1 to 20.



ABSTRACT

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5 A silicon microphone is formed using the steps of providing a first wafer including a layer of heavily doped silicon, a layer of silicon and an intermediate layer of oxide between the two silicon layers. The first wafer has a first major surface on one surface of the layer of heavily doped silicon and a second major surface on the layer of silicon. A second wafer of silicon has a first major surface and a second major surface. A layer of oxide is formed on at least the first major surfaces of the first and second wafers. A
10 cavity is etched through the oxide layer on the first major surface of the first wafer and into the layer of heavily doped silicon. The first major surface of the first wafer is bonded to the first major surface of the second wafer. The first wafer is thinned at its second major surface. A metal layer is formed on the second major surface of the second wafer. Acoustic holes are patterned and etched in the metal layer and in the
15 second major surface of the second wafer. The intermediate layer of oxide is etched from the first wafer. At least one electrode is formed on the heavily doped silicon of the first wafer and at least one electrode is formed on the second wafer.



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FIGURE 1A

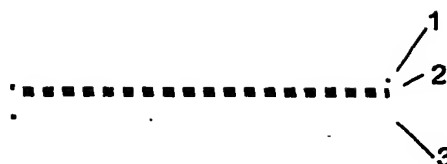


FIGURE 1B



FIGURE 2A

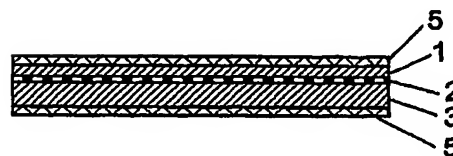


FIGURE 2B

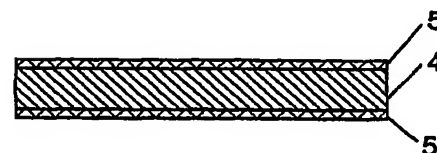


FIGURE 3

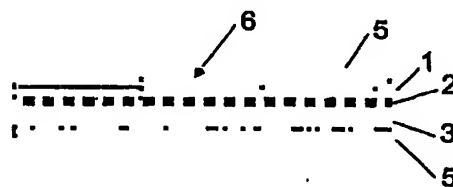


FIGURE 4

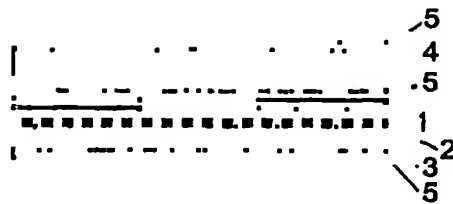


FIGURE 5

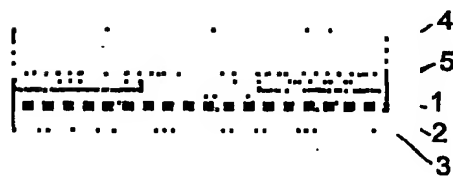


FIGURE 6

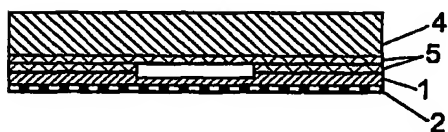


FIGURE 7

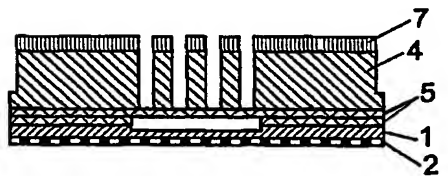


FIGURE 7A

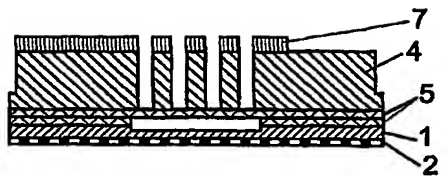


FIGURE 8

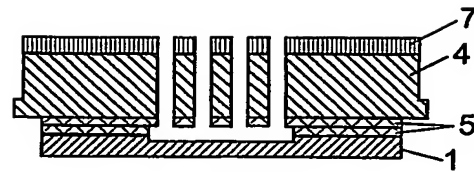


FIGURE 8A

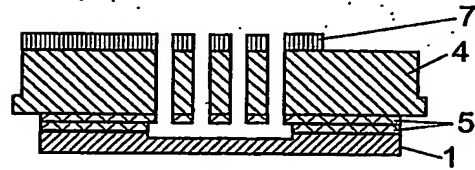


FIGURE 9

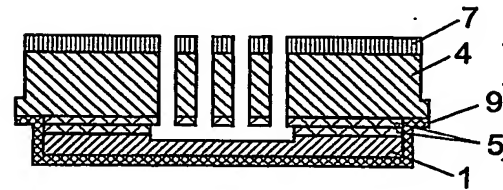


FIGURE 9A

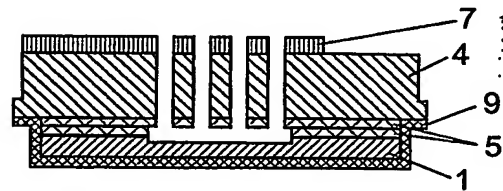


FIGURE 10

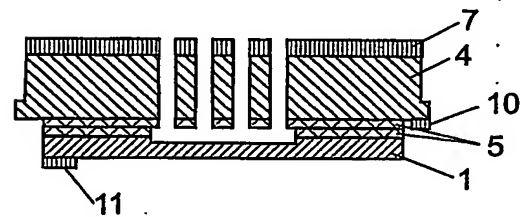


FIGURE 10A

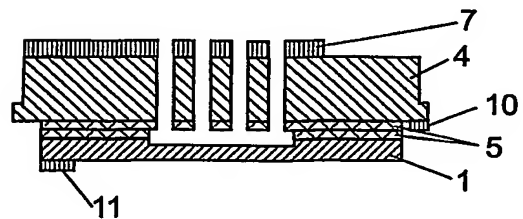


FIGURE 11

